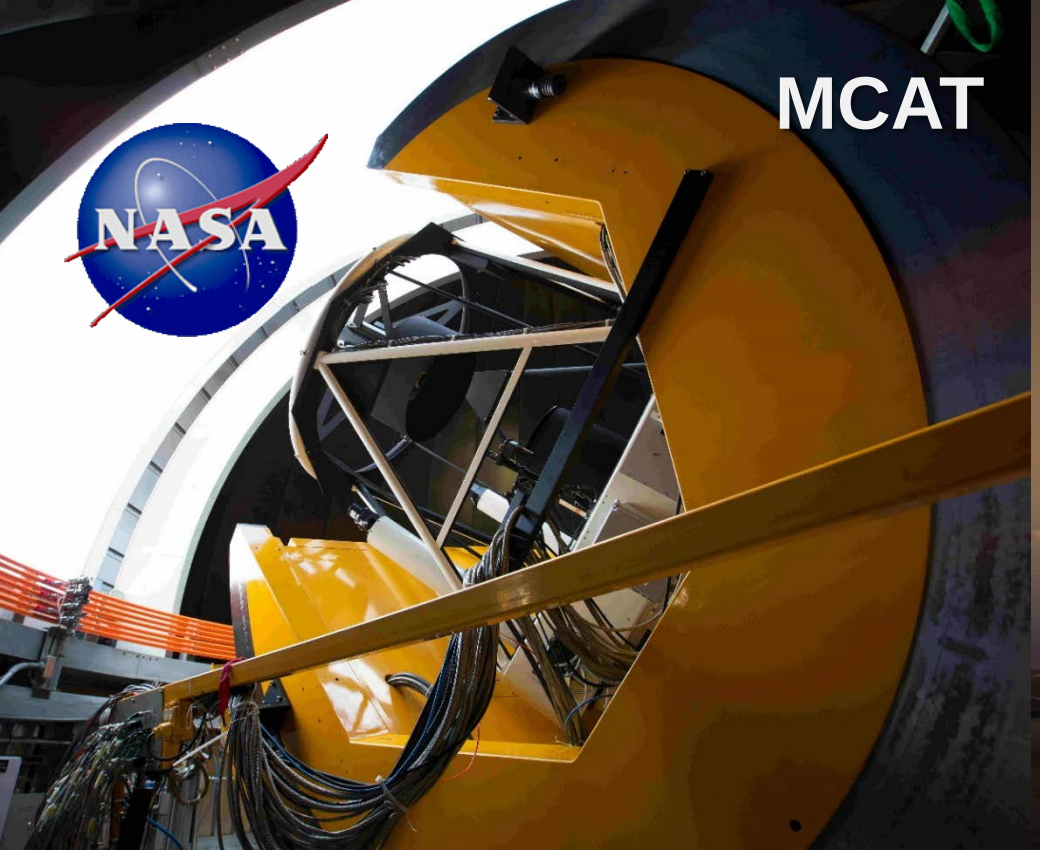


NASA OPTICAL Measurements

S. M. Lederer, NASA

Contractor Team:

J. Frith

H. M. Cowardin

B. Buckalew

J. Mcquillan (MCAT only)

B. Edwards (MCAT only)

UPDATES

- **Past-year accomplishments**
  - Instrumentation repairs: SI camera, Shutter, filter slide
  - First break-up campaign through remote obs, Jan 2016
  - Telescope fully healthy and ready for obs April 2016
  - NASA User Readiness Review held Aug 2016

- **Future goals**
  - Installation of 0.4m Benbrook telescope on nearby tower in 2017
  - Coordinated observations with MCAT/Benbrook in miniCAT config
  - Full testing of autonomous operations, all modes, both telescopes
  - Full data collections to commence
  - Establish MCAT as contributing sensor for SSN to fill GEODSS gap

MCAT Project Overview

- **Dedicated as the Eugene Stansbery Meter Class Autonomous Telescope in 2017**

- **MCAT Goal: Statistically characterize under-sampled orbital regimes**
  - Geosynchronous and near GEO altitudes
  - LILO, i.e. Low inclination Low Earth Orbit (LEO)
    - Evening and morning twilight

- **MCAT Objectives:**
  - Monitor and assess orbital debris environment by ***surveying***, ***detecting***, and ***tracking orbiting objects*** at:
    - LEO, MEO, GTO, GEO altitudes
    - GEO debris surveys

- **Ascension Island location enables access to under-sampled low inclination orbits and new GEO longitudes**

(7º 58′ S, 14º 24′ W)

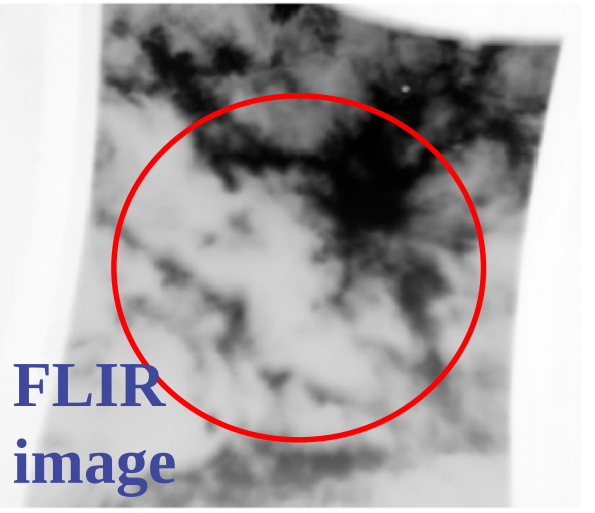
MCAT Operational Concepts (BIG PICTURE)

1. GEO Sweep/ GEO Follow-up:	2. Catalog or Object-of-Interest Tracking:	3. Orbit Scan (LEO mode):	4. Stare – Detect – Chase:	5. Coordinated Observations:
TDI mode matches GEO motion to sweep GEO longitudes; *follow-up specific targets for further characterization*	*Target specific objects for testing or characterization*	*Define rate track by a given expected orbital rate*	*Object crosses Field of View, its motion calculated, chase at calculated rate of motion*	***I.*** ***Optical-Optical*** *miniCAT* ***II.*** ***Radar-Optical***

- **5 Modes of data collection**
  - Currently testing Modes 1-3
- **Survey: Modes 1 & 3**
- **Characterization studies**
  - Mode 2 to determine individual object characteristics/orbits
  - Mode 3 for rapid follow-up after break-up event

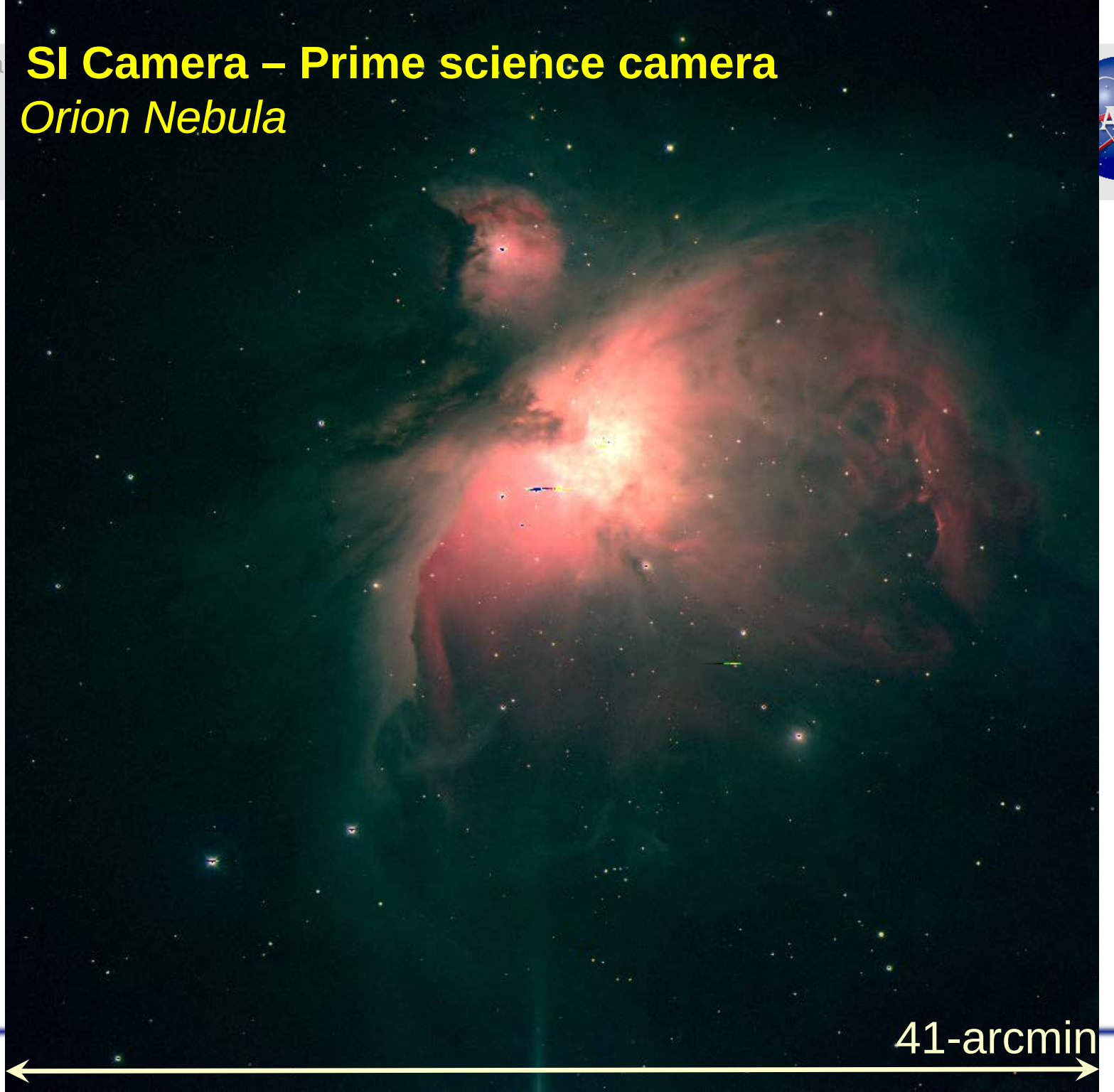
Autonomous Data Collection

- **Automated Data Collection**
  - **Start of Night**: Opens observatory fully
  - Queries 8 **weather sensors** + condensation monitor on primary → open/close
  - Queries FLIR IR camera → **sky transparency**
    - Acceptable level set by user or follows default for each observation
  - **Calibration data**: bias, flats, standard stars
  - **Debris data collects** with specified input
    - Filter, Exp-t, # exp, Lunar-angle, Sun-altitude, object illumination, priority etc.
  - **Tracking**
    - sidereal, TLE, user-defined 7-element vector, TDI (GEO survey), HA, RA rate
    - Simultaneous/coordinated obs with miniCAT telescope
      - ➢ Same modes, different filters possible
    - Using SGP4, SDP4
  - **End of Night**: Closes observatory fully



SI Camera – Prime science camera

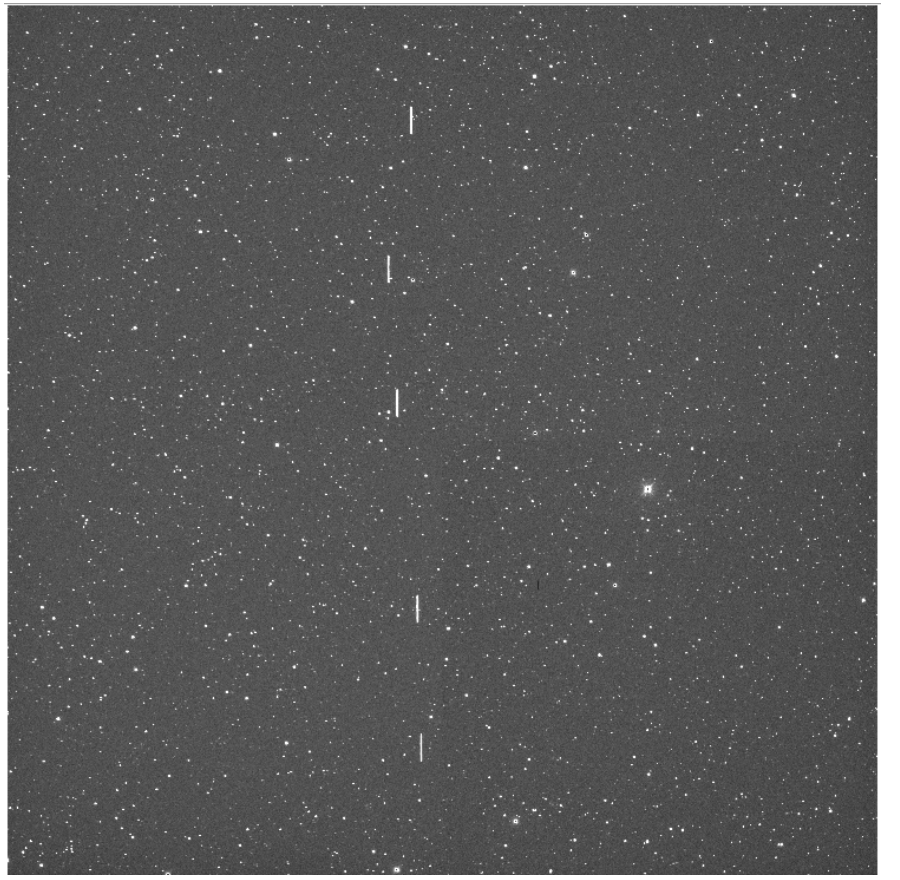
Orion Nebula



MCAT Sidereal Tracking

Standard star field: Landolt 99_438

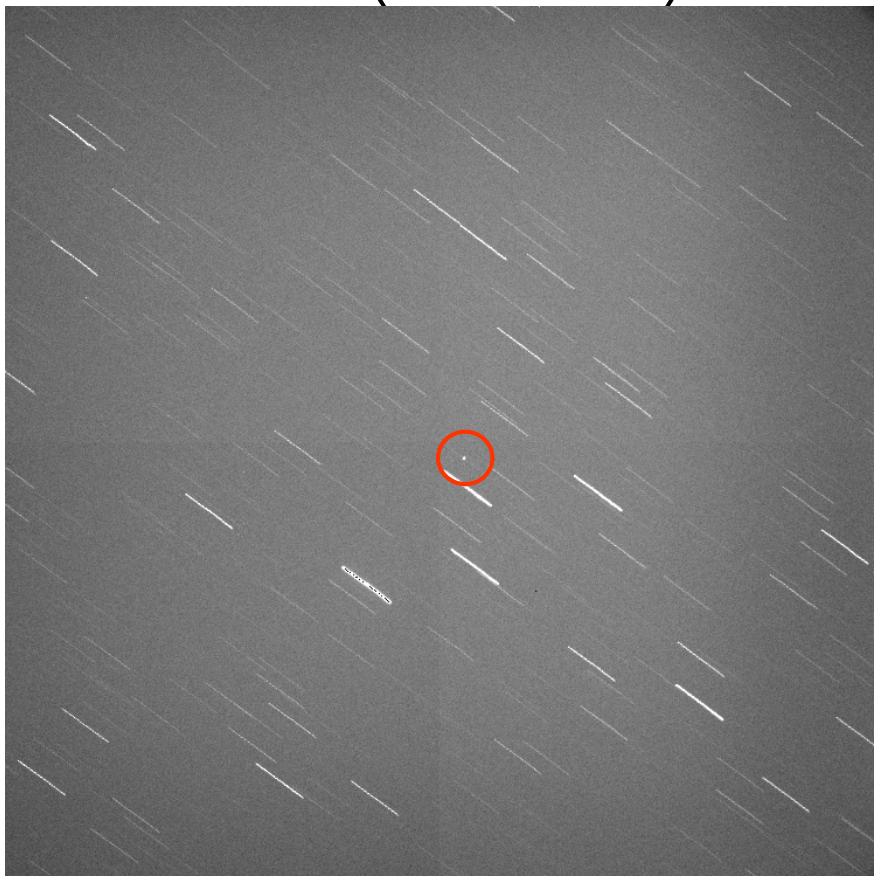
GEO cluster, stare mode



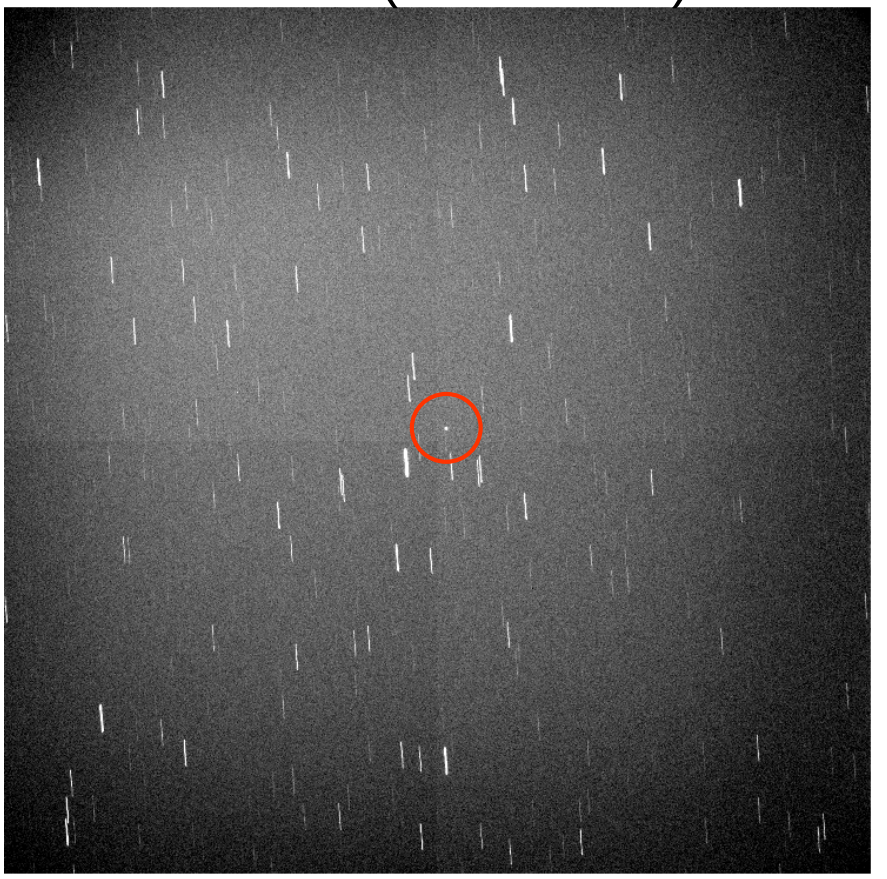
- Tracking at the rate of stars

MCAT Object Tracking (TLE)

MEO (SSN 41019)



GEO (SSN 27389)



- MEO, GEO object tracking with MCAT

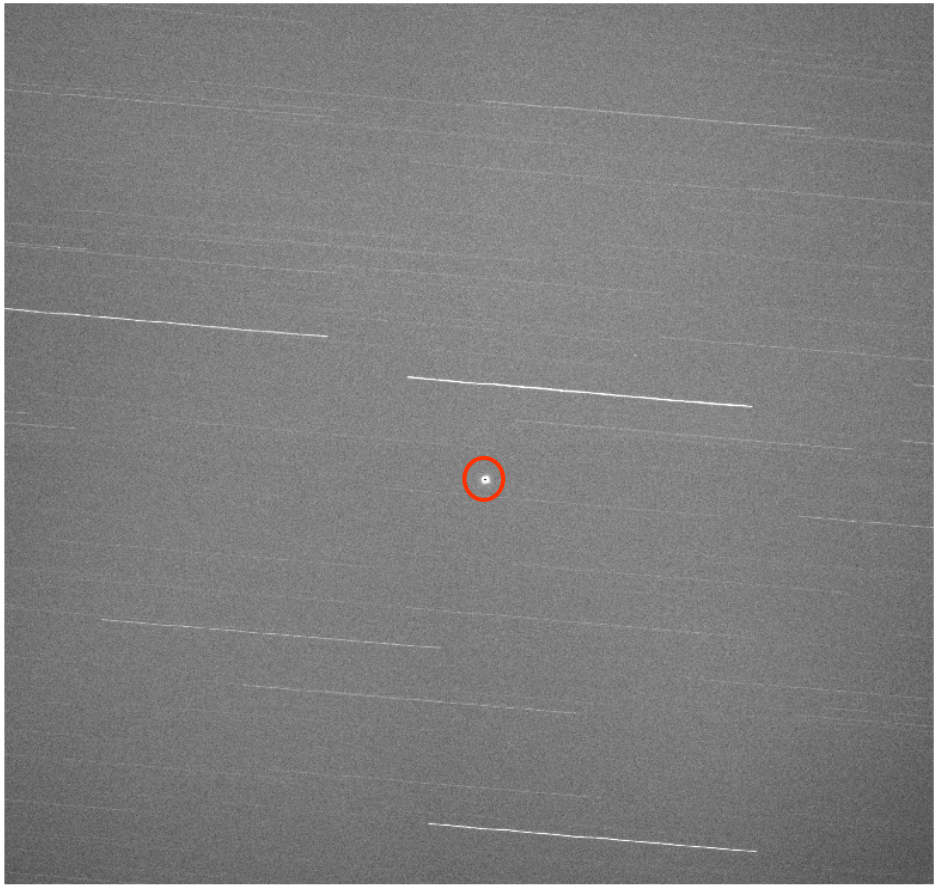
MCAT Object Tracking (TLE)

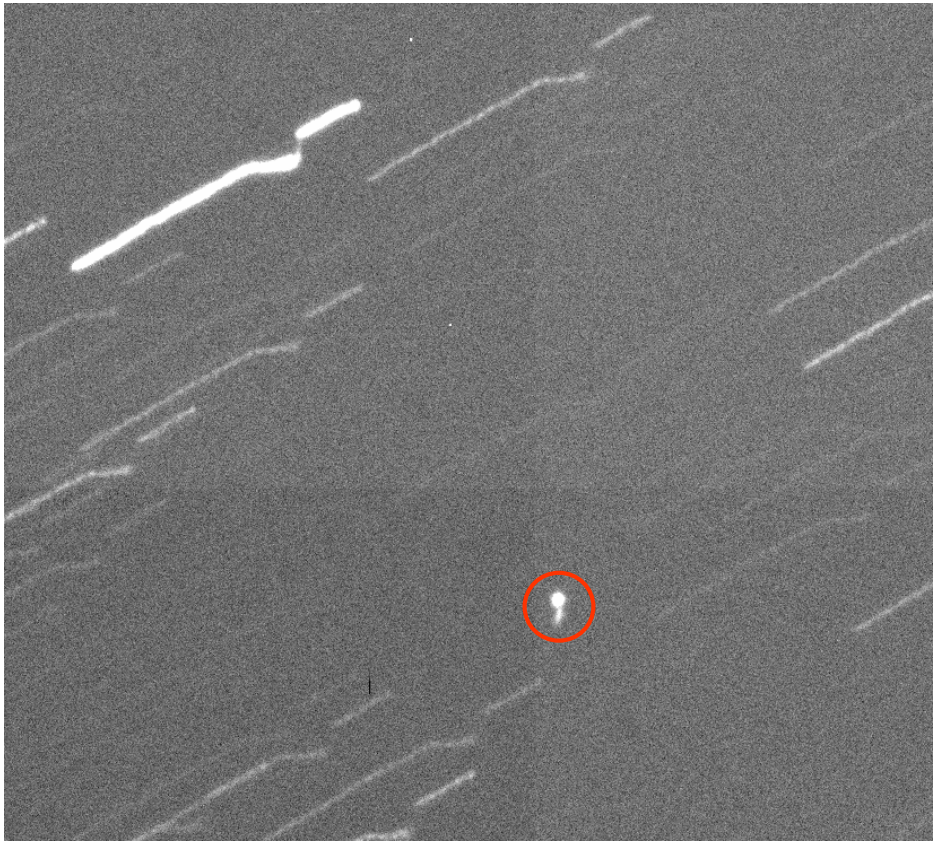
LEO tracking (SSN 40062)

- LEO object tracking with MCAT

MCAT Object Tracking (TLE)

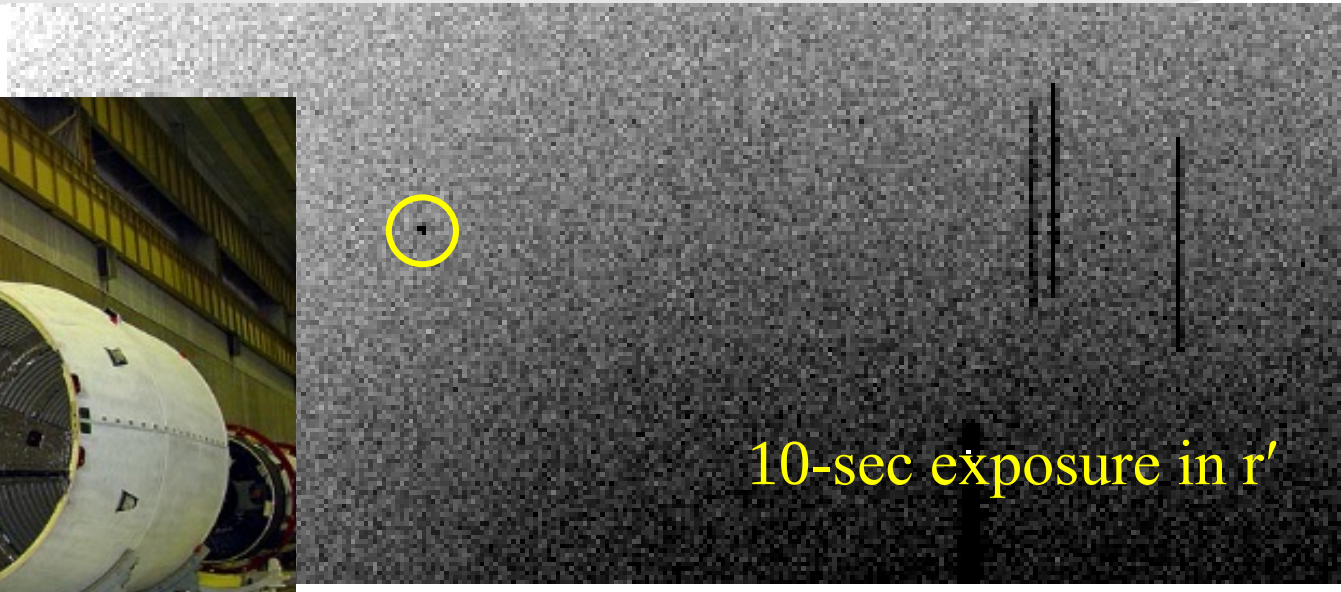
LEO tracking (SSN 40062)





- LEO object tracking with MCAT
- We think we've resolved this!

BRIZ-M Rocket Body Breakup Identified in 2016



- Broke up ~1 month after launch
- Inserted into GEO orbit
- MCAT observed in 2016, shortly after break-up was publically announced

0.4m Telescope

- **Raven-class system design**
- **Instrumentation**
  - 0.4m Officina Stellare telescope
  - LEO tracking Astelco mount
  - Finger Lakes Proline camera
    - 2048x2048 = **44' x 44'**
      (vs. MCAT = 41' x 41')
    - Also very sensitive e2V CCD
    - 1.3" per pixel (vs. 0.6"/pix MCAT)
  - 10-position filter wheel
    - Sloan g' r' i' z'
    - BVRI
    - Matches MCAT
- **DIMM or miniCAT Configs**
- **Simultaneous observations with MCAT in 2 filters!**

MCAT Timeline

New since last meeting: **in bold**

Systems Testing

- July 2013: Telescope testing
- Aug 2013-June 2014: Software/Hardware integration testing

Construction

- Sept 2014, Ground-breaking
- Sept-March/April 2015: Main facility construction
- March-April 2015: Dome installation
- April-June 2015: Telescope installation

Acceptance Testing

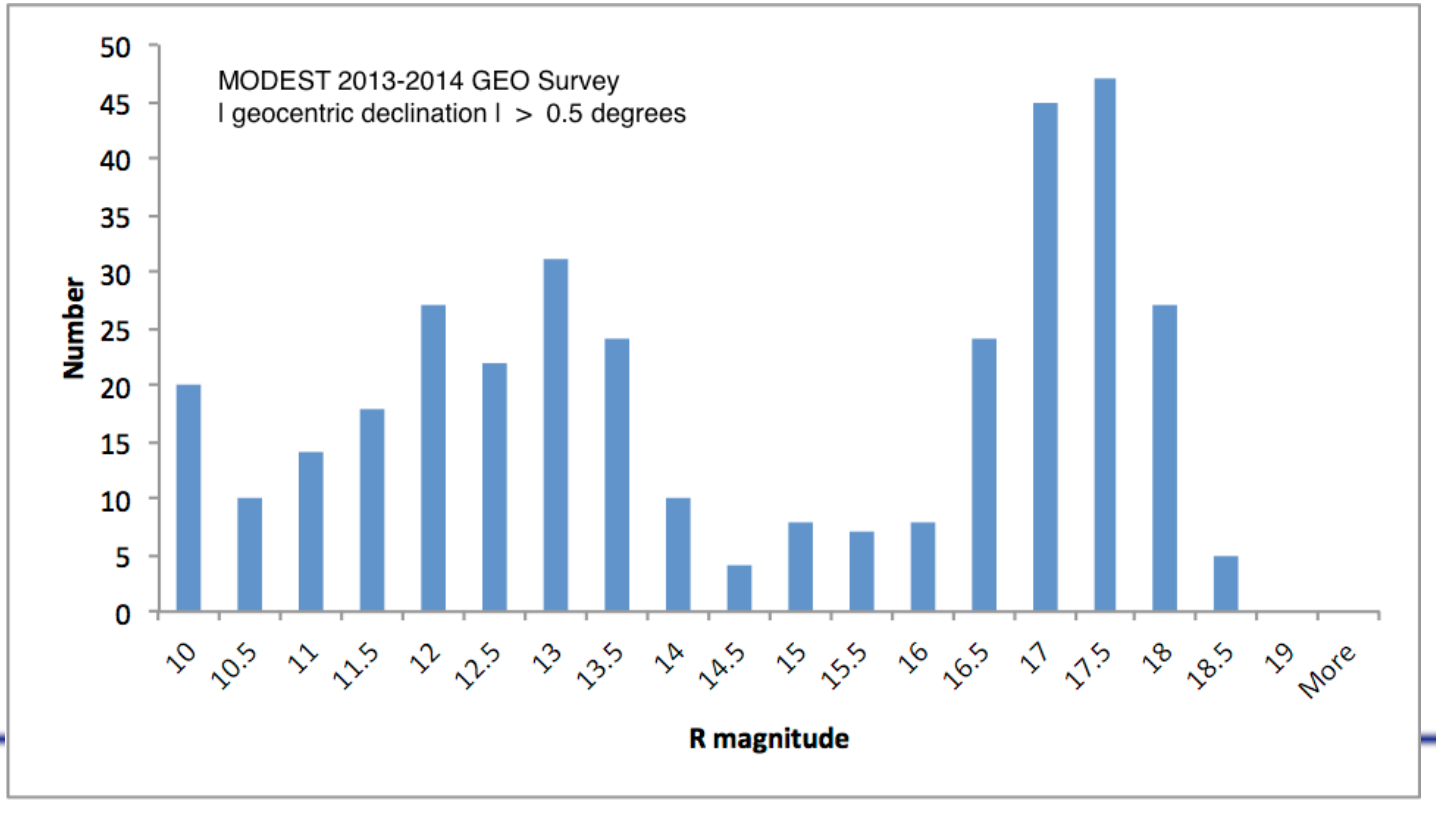
- June 2, 2015: Engineering First light
- June17: Camera failure
- SAT for all except Camera-specific tasks
- Aug: 1st Light alt camera for debris tracking, lightcurves
- Nov: SI Camera fix
- Dec 2015: SI Camera

Full Integration/ Data Collection

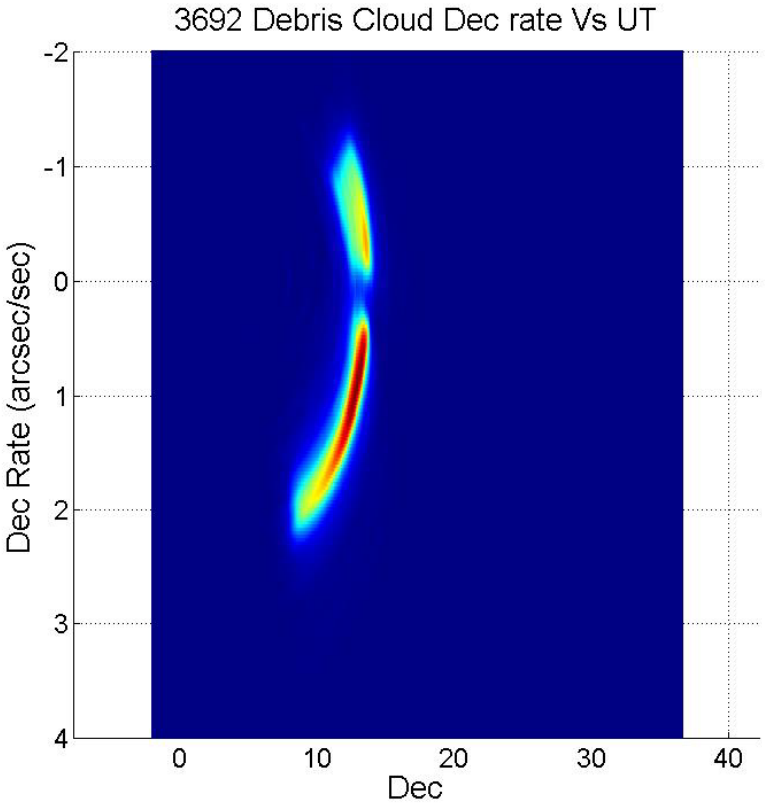
- Jan 2016: Remote Data collects possible
- 2016: Begin MCAT integrated systems testing
- **Aug/Nov 2016: URR**
- **2017: 0.4m scope install**
- **Full operations expected 20+ years**

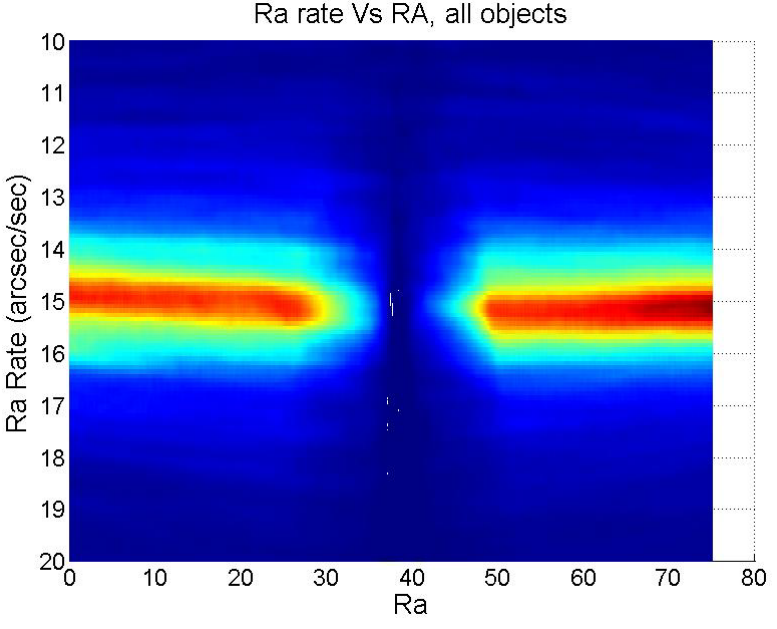
MODEST 2013-2014 GEO Survey Details

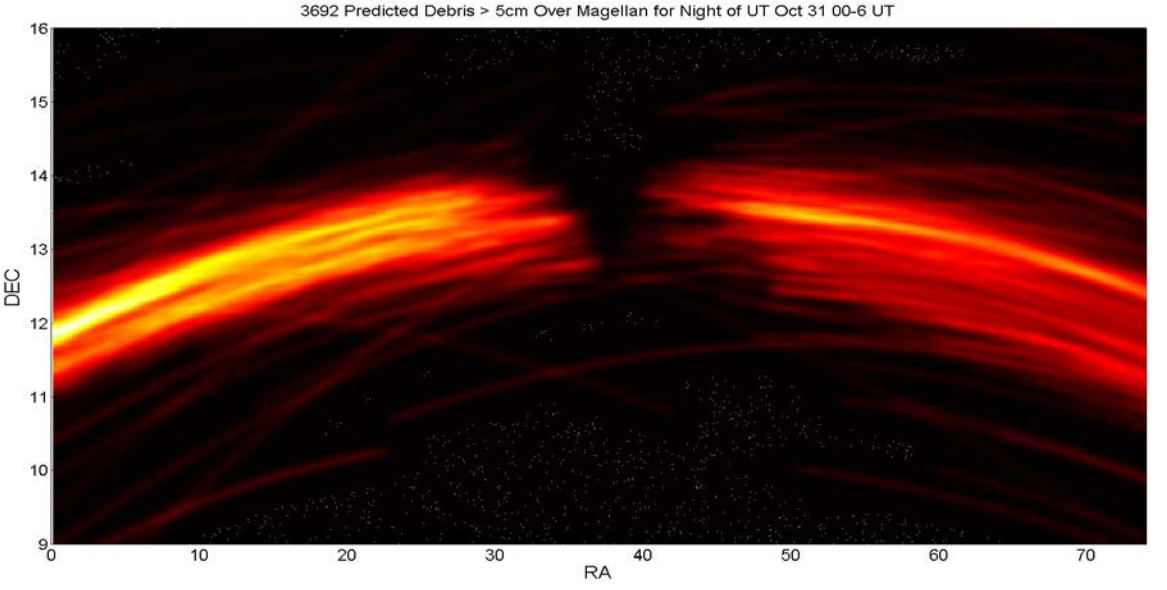
- **Consider fields away from GEO belt of station-keeping objects.**
  - | Geocentric declination | > 0.5 deg
- **15 photometric nights total.** July, Dec 2013; Feb, June 2014
  - 351 objects with 4 or more individual detections.
  - 2014 was last year of MODEST GEO survey for NASA.
- **Preliminary Analysis indicates pipeline is working**



Magellan: 3692 Titan Debris cloud

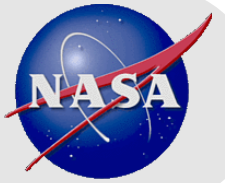






- Oct 2015
- 3692 Titan 3C Transtage
- Break-up survey
- NASA Standard Satellite Breakup Model (SSBM) simulated debris cloud

Optical Measurements Center



- **Past- year Accomplishments**
  - Spectral measurements/analysis on Titan Transtage samples removed from Transtage while stored in “Boneyard” in Tucson, Arizona
  - HS-376 bus study: Spectral measurements/analysis on solar cells (for comparison with telescopic data)

- **Long-term project goals**
  - Continuous acquisition of broad-band lightcurve data and BRDF measurements to support characterization of orbital debris.
  - Database to include photometric, spectroscopic, and other physical data measurements.
  - Develop optical Size Estimation Model (OSEM) comparable to the existing radar-based SEM from DebriSat fragments

UKIRT

United Kingdom Infrared Telescope

Mauna Kea, Hawaii

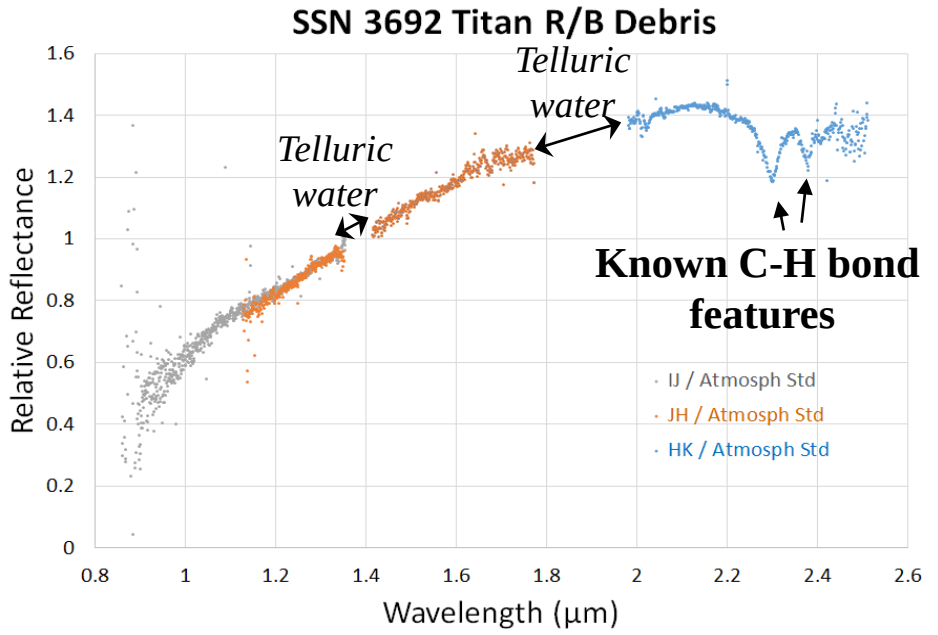
United Kingdom Infrared Telescope (UKIRT)

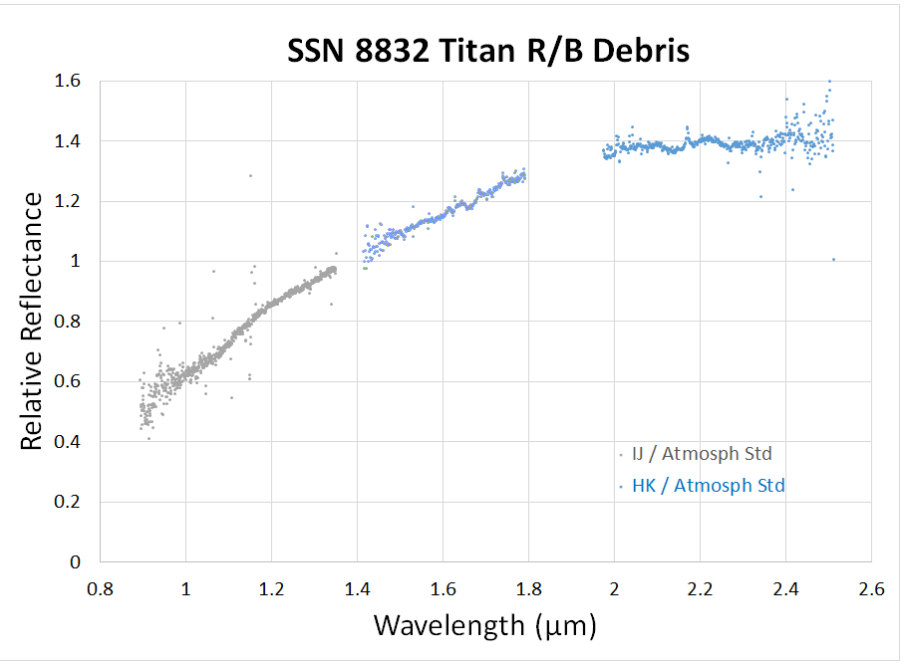
30+ years of operations supporting advanced astronomical science.

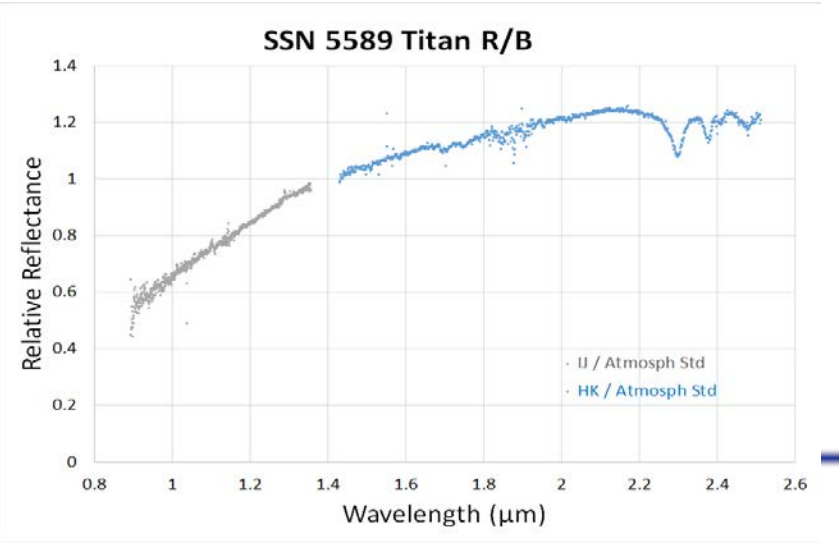
- **UKIRT**
  - **3.8 meter telescope**
  - Optimized for near-mid infrared (0.8 – 25 μm)

- **UIST Spectrometer/Imager** 0.85 – 5 μm
  Near infrared absorption bands can be used to identify debris materials of spacecraft by modeling with spectral database input

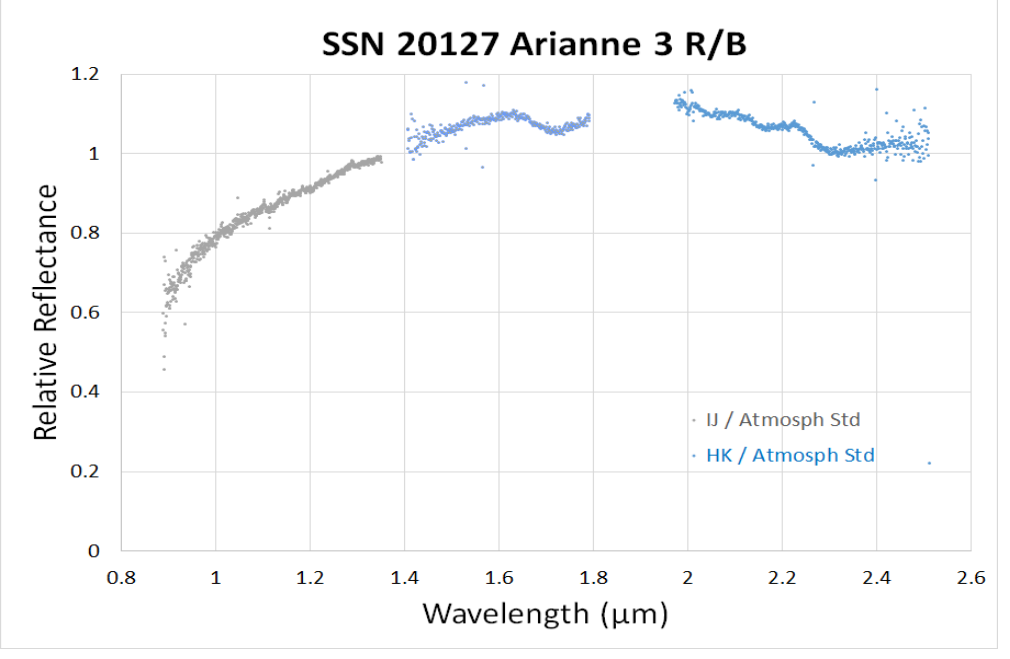
Titan Rocket Body Debris

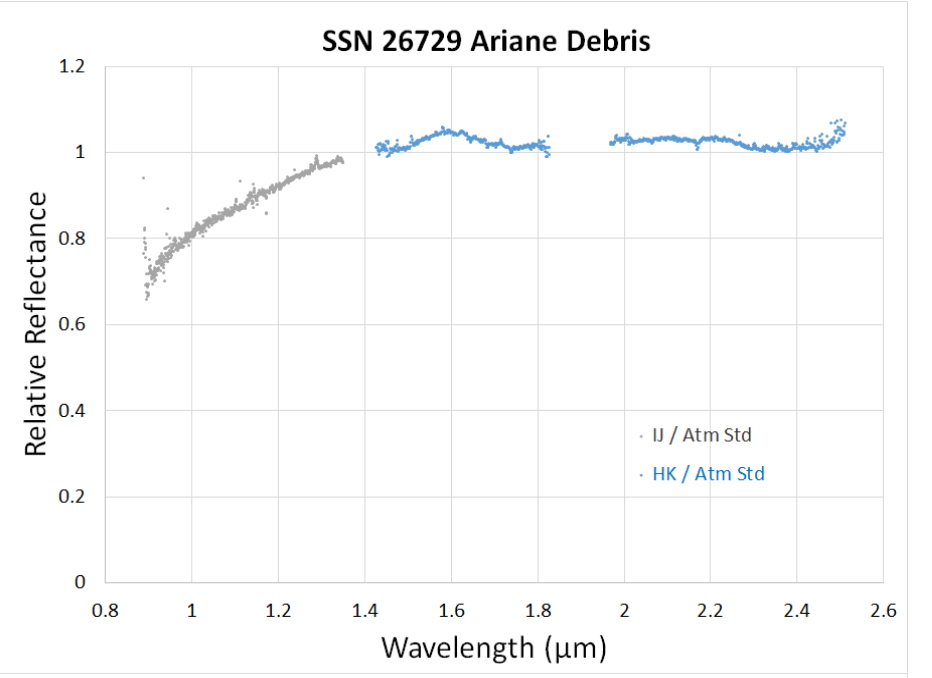


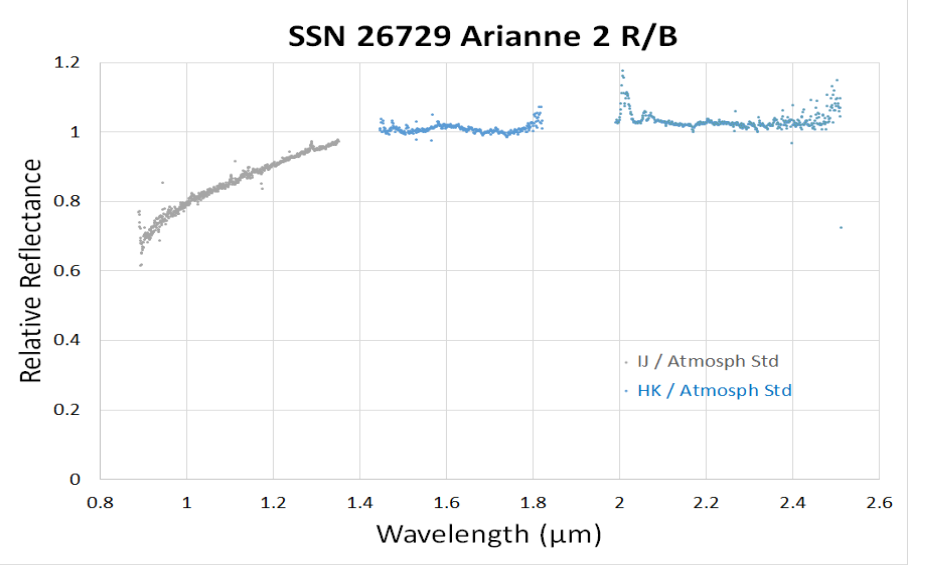




Arianne 2 & 3: in-tacts





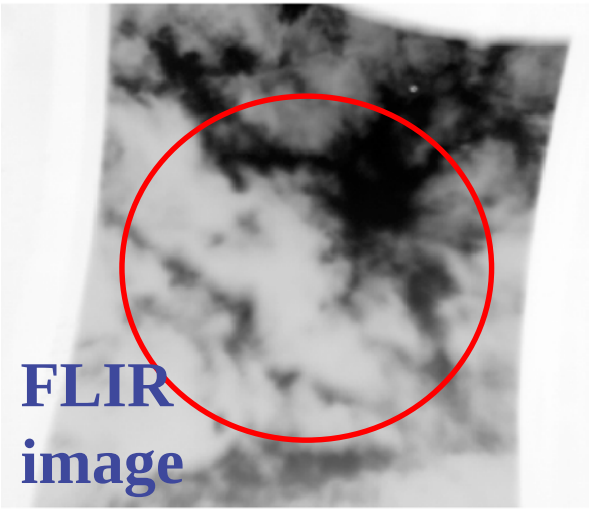


Any Questions?

Instrumentation: Weather, Clouds & All-Sky

Weather equipment

- **Weather station/sensors: 5 types (7 total)**
  - Temperature, Pressure
  - Wind speed average & direction
  - Humidity, dewpoint
  - Rain sensors
  - Cloud sensors
- **All-Sky cam**
  - View of the whole sky to determine cloud location and observing strategy
- **FLIR Infrared Cam** (on MCAT secondary mirror)
  - Cloud analysis/Photometric Conditions



Sky Brightness

- Sky Brightness average (no moon): **21.3 – 21.7 mag/sq-arcsec**

Winds

- 17-20mph average sustained winds, SE/SSE

Seeing

- Initial estimates: 1.0 – 1.25"